Jacobs Challenging today. Reinventing tomorrow.

Longer Shock Pulse Width Study Preliminary Data Review

Benny Damron, Jacobs Space Exploration Group, NASA Marshall Space Flight Center

Christian Schuler, Naval Surface Warfare Center Crane Division

April 19, 2022

1. Task Group Composition
2. Metrics
3. Action Items From January 2022 Meeting
4. Initial PIND Samples Sent to NSWC Crane
    1. First Group of Packages
    2. Second Group of Packages
5. PIND Equipment Used For Testing
6. NSWC Crane Standard Shock Pulse Width PIND Test Results Observations
7. Package Detection Anomaly Evaluation
8. Future plans

PIND Task Group Members

- PIND Task Group Work participant members represent the manufacturers, industry, and government agencies, and international partners:
  - Manufacturers: Microchip, Texas Instruments, IR Hi Rel/ Infineon, VPT Components, Semicoa, Teledyne Microwave Solutions, Micropac Industries Inc.
  - Industry Test Laboratories – Hi Rel Labs, ORS Labs, Golden Altos
  - Government Agencies and their contractors – NASA, NSWC Crane Division, US Air Force, US Army, Aerospace Corporation, DLA Land and Maritime,
  - International Partners – ESA, NASAM, TESAT/ DLR

Metrics

- Conducted 2 PIND Webex/ Teleconferences since January 2022 JEDEC meeting
- Meetings held on monthly basis
- Average meeting attendance was (10).

Action Item Number 1

- Recommendation at the last meeting that the task group develop a charter to define the scope of the task group's efforts.

- Proposed charter: Purpose is to perform a PIND study to determine whether particle detection in small packages is improved using a longer width shock pulse over the standard PIND width shock pulse.

- Study Methodology: Sample devices utilized for this study consist of units seeded with various type particles commonly used during the assembly of these devices, nonseeded, reject units (electrical, PIND, Xray etc), and known good devices (no particles) in various package types. PIND testing of samples will be performed at NSWC Crane, NASA MSFC, Spectral Dynamics, and B&W Engineering. Results of this initial study may require follow-on study with more test facility participants.

Action Item Number 2

- NSWC Crane had problem doing shock pulse characterization with their equipment. Observed that their B&W PIND tester comes with an accelerometer to verify their shock pulse.
- Need to procure 50-ohm Oscilloscope cables to verify shock pulse.

- Action item: Christian Schuler, NSWC Crane to check with their lab personnel to verify they can measure at 50% of pulse height.

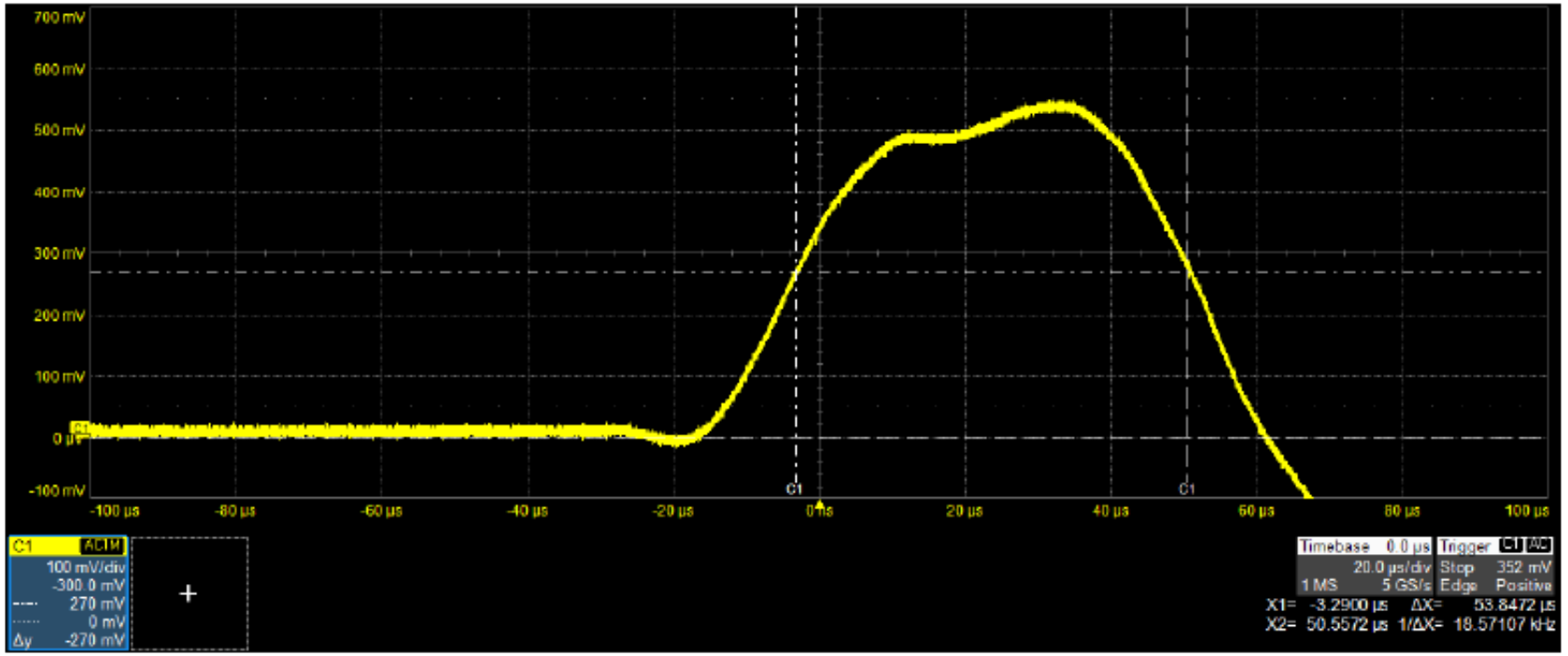
- Result: NSWC Crane has been able to measure the shock pulse width of their B&W Engineering PIND test equipment.

Action Item Number 2

- Measurement procedure –
  - Capture first half period of the 1000G shock pulse wave form.
  - Measure the peak amplitude (A_{max}).
  - Measure the time difference between the rising edge (t_r) and the falling edge (t_f) of the waveform A_{max} level of the shock pulse

- Result: NSWC Crane has been able to measure the shock pulse width of their B&W Engineering PIND test equipment. Shock pulse width was measured to be approximately 54 µs at the 50 percent level

Action Item Number 3



- Measured at the 50 percent point of the shock pulse
- Shock pulse width is approximately 54 µsec.

Status Since January 2022 JEDEC Meeting

- NASA MSFC Covid19 status is stage 2, so this effort at MSFC has been temporarily suspended:
- 39 PIND samples have been sent to NSWC Crane for the first PIND testing.
- NSWC Crane created test travelers, determined cavity heights for the 39 devices and calculated test frequencies to use.
- Testing completed on the first group of samples at NSWC Crane.

Initial PIND Samples PIND Tested by NSWC Crane

- 39 Sample parts tested.

Package Type	Quantity
121 PGA	2
8 pin cerdip	2
8 pin side braze	2
20 pin LCC	2
31 PGA	1
32 pin CQFP	2
TO-5 4 ld	2
14 pin FP	2
DO-13	5
TO-18	5
UB	4
UA	4
TO-39	3
UMC	3
Total Sample Count	39

Initial PIND Samples PIND Tested by NSWC Crane

- Second group of 62 sample packages sent to NSWC Crane and ready to be PIND tested with standard shock pulse PIND equipment.

Package Type	Quantity	change
TO-254	20	
UB	12	
16 pin flat pack	7	
7 pin flat pack	3	
SMD.5 (U3)	20	
Total Sample Count	62	

PIND Test Equipment and Process Used by NSWC Crane

- PIND Test Equipment Manufacturer – B&W Engineering
- PIND Test Equipment Model and serial number – BW-LPD-DAQ-4000, Serial number 6083.
- Test frequencies were calculated using the internal package height as per the test method equation.
- PIND Test equipment shock pulse width has not been modified.

NSWC Crane Standard Shock Pulse Width PIND Test Results Observations

- TO-39 packages serial numbers 87, 88, 89 – no particle detection observed during either test run. Two of three devices were PIND failures initially. One of the packages is a known good sample.

- TO-5 package serial number 77 – no particle detection observed during either test run.

- TO-5 package serial number 78 – no particle detection observed during first test run. Particle detection was observed during second test run for each vibration sequence.

NSWC Crane Standard Shock Pulse Width PIND Test Results Observations

- UB package serial number 37 registered particle detection during 3 of 4 vibration sequences on 1st test run and only the 1st of 4 vibration sequences during 2nd test run

- UA package, serial number 60, registered a particle detection during every vibration sequence when it shouldn't have.

- UA package serial number 71 registered a particle detection on 1st of 4 vibrations on 1st and 2nd test runs.

- UMC package serial numbers 1 and 3 registered a particle detection during all vibration sequences on 1st test run. No particle detection was registered during 2nd test run.

Package Detection Anomaly Evaluation

- Plan for testing package types with detection anomalies from first group of packages tested.
- X-ray the following package serial numbers and look for FOD. Check to see if FOD moves by rotating parts and record location of FOD.
  - TO-39 – serial numbers 87, 88, and 89
  - TO-5 – serial numbers 77 and 78
  - UB – serial number 37
  - UA – serial numbers 60 and 70
  - SMC – serial numbers 1, 2, and 3
- PIND test these units and record results.
- X-ray the suspect packages again and record whether FOD has moved.
- Similar testing will be performed if any PIND detection anomalies are found during testing of second group of packages.

Longer Shock Pulse Width Task Proposal Future Plans

- Perform the X-ray and FOD check on the packages with anomalies from the first group tested.
- Develop travelers and schedule PIND testing of second group of samples at NSWC Crane. Then send samples to MSFC for testing.
- Will ask manufacturers for specific quantities for some of the 1- or 2-piece samples received.

Thank you!

- We would like to express our appreciation to the task group members, NASA NEPAG and SLS programs, Government Working Group, and NSWC Crane for their continued support of this effort.

- Contact information:

Benny Damron
Jacobs Space Exploration Group (JSEG)
NASA Marshall Space Flight Center
Benny.Damron@nasa.gov

Christian Schuler
NSWC Crane Division
christian.d.schuler.civ@us.navy.mil

Acronyms

- DLA – Defense Logistics Agency
- DLR – German Aerospace Center
- DPA – Destructive Physical Analysis
- ESA – European Space Agency
- ESD – Electrostatic Discharge
- FOD – Foreign Object Debris
- JEDEC – JEDEC Solid State Technology Association
- NASA – National Aeronautics and Space Administration
- MSFC- Marshall Space Flight Center
- NSWC Crane – Naval Surface Warfare Center, Crane Division
- PIND – Particle Impact Noise Detection
- STU – Sensitivity Test Unit

- Backup Data

NSWC Crane Standard Shock Pulse Width PIND Test Results All Test Runs Table 2

Table 2. Test Facility PIND detection results for standard shock pulse width (~40 uS)

Test Facility NSWC CRANE Standard PIND Test Results

PIND Equipment Manufacturer B&W PIND Equipment Model number BW-LPD-DAQ4000 SN 6083

Lot number (Traveler number)	Package Type	Serial number	Pulse Width in uS	Shock pulse in g's		Vibration detection				
					Run #	Vib 1	Vib 2	Vib 3	Vib 4	Pass/Fail
JDC035SPT	121 PGA	135	40	1000	1	X	X	X	X	Fail
JDC035SPT	121 PGA	135	40	1000	2	X	X	X	X	Fail
JDC035SPT	121 PGA	143	40	1000	1	X	X	X	X	Fail
JDC035SPT	121 PGA	143	40	1000	2	X	X	X	X	Fail
JDC036SPT	8 PIN CERDIP	8	40	1000	1	X	X	X	X	Fail
JDC036SPT	8 PIN CERDIP	8	40	1000	2	X	X	X	X	Fail
JDC036SPT	8 PIN CERDIP	91	40	1000	1	X	X	X	X	Fail
JDC036SPT	8 PIN CERDIP	91	40	1000	2	X	X	X	X	Fail
JDC037SPT	8 PIN SIDE BRAZED	241	40	1000	1	X	X	X	X	Fail
JDC037SPT	8 PIN SIDE BRAZED	241	40	1000	2	X	X	X	X	Fail
JDC037SPT	8 PIN SIDE BRAZED	247	40	1000	1	X	X	X	X	Fail
JDC037SPT	8 PIN SIDE BRAZED	247	40	1000	2	X	X	X	X	Fail
JDC038SPT	20 PIN LCC	5	40	1000	1	X	X	X	X	Fail
JDC038SPT	20 PIN LCC	5	40	1000	2	X	X	X	X	Fail
JDC038SPT	20 PIN LCC	6	40	1000	1	X	X	X	X	Fail
JDC038SPT	20 PIN LCC	6	40	1000	2	X	X	X	X	Fail

NSWC Crane Standard Shock Pulse Width PIND Test Results All Test Runs Table 2 (Cont'd)

Table 2. Test Facility PIND detection results for standard shock pulse width (~40 uS)

Test Facility NSWC CRANE Standard PIND Test Results

PIND Equipment Manufacturer B&W PIND Equipment Model number BW-LPD-DAQ4000 SN 6083

Lot number (Traveler number)	Package Type	Serial number	Pulse Width in uS	Shock pulse in g's	Run #	Vibration detection				Pass/Fail
						Vib 1	Vib 2	Vib 3	Vib 4	
JDC039SPT	32 PIN PGA	201	40	1000	1	X	X	X	X	Fail
JDC039SPT	32 PIN PGA	201	40	1000	2	X	X	X	X	Fail
JDC040SPT	32 PIN CQFP	11	40	1000	1	X	X	X	X	Fail
JDC040SPT	32 PIN CQFP	11	40	1000	2	X	X	X	X	Fail
JDC040SPT	32 PIN CQFP	21	40	1000	1	X	X	X	X	Fail
JDC040SPT	32 PIN CQFP	21	40	1000	2	X	X	X	X	Fail
JDC041SPT	14 PIN FP	3	40	1000	1	X	X	X	X	Fail
JDC041SPT	14 PIN FP	3	40	1000	2	X	X	X	X	Fail
JDC041SPT	14 PIN FP	4	40	1000	1	X	X	X	X	Fail
JDC041SPT	14 PIN FP	4	40	1000	2	X	X	X	X	Fail
JDC100SPT	TO-18	82	40	1000	1	X	X	X	X	Fail
JDC100SPT	TO-18	82	40	1000	2	X	X	X	X	Fail
JDC100SPT	TO-18	86	40	1000	1					Pass
JDC100SPT	TO-18	86	40	1000	2					Pass
JDC100SPT	TO-18	99	40	1000	1	X	X	X	X	Fail
JDC100SPT	TO-18	99	40	1000	2	X	X	X	X	Fail

NSWC Crane Standard Shock Pulse Width PIND Test Results All Test Runs Table 2 (Cont'd)

Table 2. Test Facility PIND detection results for standard shock pulse width (~40 uS)

Test Facility NSWC CRANE Standard PIND Test Results

PIND Equipment Manufacturer B&W PIND Equipment Model number BW-LPD-DAQ4000_SN 6083

Lot number (Traveler number)	Package Type	Serial number	Pulse Width in uS	Shock pulse in g's	Run #	Vibration detection				Pass/Fail
						Vib 1	Vib 2	Vib 3	Vib 4	
JDC100SPT	TO-18	108	40	1000	1	X	X	X	X	Fail
JDC100SPT	TO-18	108	40	1000	2	X	X	X	X	Fail
JDC100SPT	TO-18	119	40	1000	1	X	X	X	X	Fail
JDC100SPT	TO-18	119	40	1000	2	X	X	X	X	Fail
JDC101SPT	TO-39	87	40	1000	1					?
JDC101SPT	TO-39	87	40	1000	2					?
JDC101SPT	TO-39	88	40	1000	1					Pass
JDC101SPT	TO-39	88	40	1000	2					Pass
JDC101SPT	TO-39	89	40	1000	1					?
JDC101SPT	TO-39	89	40	1000	2					?
JDC102SPT	TO-5	77	40	1000	1					?
JDC102SPT	TO-5	77	40	1000	2					?
JDC102SPT	TO-5	78	40	1000	1					?
JDC102SPT	TO-5	78	40	1000	2	X	X	X	X	Fail

Highlighted rows identify anomalies.

NSWC Crane Standard Shock Pulse Width PIND Test Results All Test Runs Table 2 (Cont'd)

Table 2. Test Facility PIND detection results for standard shock pulse width (~40 uS)

Test Facility NSWC CRANE Standard PIND Test Results

PIND Equipment Manufacturer B&W PIND Equipment Model number BW-LPD-DAQ4000_SN 6083

Lot number (Traveler number)	Package Type	Serial number	Pulse Width in uS	Shock pulse in g's	Run #	Vibration detection				Pass/Fail
						Vib 1	Vib 2	Vib 3	Vib 4	
JDC150SPT	DO-13	205	40	1000	1	X	X	X	X	Fail
JDC150SPT	DO-13	205	40	1000	2	X	X	X	X	Fail
JDC150SPT	DO-13	206	40	1000	1					Pass
JDC150SPT	DO-13	206	40	1000	2					Pass
JDC150SPT	DO-13	213	40	1000	1	X	X	X	X	Fail
JDC150SPT	DO-13	213	40	1000	2	X	X	X	X	Fail
JDC150SPT	DO-13	237	40	1000	1	X	X	X	X	Fail
JDC150SPT	DO-13	237	40	1000	2	X	X	X	X	Fail
JDC150SPT	DO-13	238	40	1000	1	X	X	X	X	Fail
JDC150SPT	DO-13	238	40	1000	2	X	X	X	X	Fail
JDC151SPT	UB	2	40	1000	1	X	X	X	X	Fail
JDC151SPT	UB	2	40	1000	2	X	X	X	X	Fail
JDC151SPT	UB	26	40	1000	1					Pass
JDC151SPT	UB	26	40	1000	2					Pass
JDC151SPT	UB	36	40	1000	1	X	X	X	X	Fail
JDC151SPT	UB	36	40	1000	2	X	X	X	X	Fail
JDC151SPT	UB	37	40	1000	1	X	X		X	Fail
JDC151SPT	UB	37	40	1000	2	X				Fail

Highlighted rows identify anomalies.

NSWC Crane Standard Shock Pulse Width PIND Test Results All Test Runs Table 2 (Cont'd)

Table 2. Test Facility PIND detection results for standard shock pulse width (~40 uS)

Test Facility NSWC CRANE Standard PIND Test Results

PIND Equipment Manufacturer B&W PIND Equipment Model number BW-LPD-DAQ4000 SN 6083

Lot number (Traveler number)	Package Type	Serial number	Pulse Width in uS	Shock pulse in g's		Vibration detection				
					Run #	Vib 1	Vib 2	Vib 3	Vib 4	Pass/Fail
JDC152SPT	UA	58	40	1000	1	X	X	X	X	Fail
JDC152SPT	UA	58	40	1000	2	X	X	X	X	Fail
JDC152SPT	UA	60	40	1000	1	X	X	X	X	Fail
JDC152SPT	UA	60	40	1000	2	X	X	X	X	Fail
JDC152SPT	UA	68	40	1000	1	X	X	X	X	Fail
JDC152SPT	UA	68	40	1000	2	X	X	X	X	Fail
JDC152SPT	UA	71	40	1000	1	X				Fail ?
JDC152SPT	UA	71	40	1000	2	X				Fail ?
JDC153SPT	UMC	1	40	1000	1	X	X	X	X	Fail
JDC153SPT	UMC	1	40	1000	2					Fail ?
JDC153SPT	UMC	2	40	1000	1					Pass
JDC153SPT	UMC	2	40	1000	2					Pass
JDC153SPT	UMC	3	40	1000	1	X	X	X	X	Fail
JDC153SPT	UMC	3	40	1000	2					?

Highlighted rows identify anomalies.

Longer Shock Pulse Width Task

- Background of particle detection in small packages discussion in Task Group Work
- Longer shock pulse width proposal – how did we get here?
- Longer shock pulse width particle detection test plan

Longer Shock Pulse Width Task Background

- MIL-STD-750 Test Methods Task Group Work
  - Task Group evaluated PIND particle detection as follows:
    - Three MIL-PRF-19500 suppliers performed controlled PIND testing of seeded and non-seeded devices
    - Vibration frequencies >130Hz depending on package tested
    - Location of device under test on transducer/ shaker
    - Three component suppliers PIND tested a mix of UB, TO-18, TO-39, LCC-18, SMD-0.5, and TO-254 packages

Longer Shock Pulse Width Task Background

- Performed PIND at 130hz, 140hz, 150hz, and 200hz on 1x3 mil aluminum wire. One unit was tested 10 times in succession in the center of transducer.
  - 130hz 8/10 detect
  - 140hz 8/10 detect
  - 150hz 9/10 detect
  - 200hz 8/10 detect

Longer Shock Pulse Width Task Background

- For smaller cavity packages position on the transducer is very significant, as verified by multiple manufacturers. Smaller packages specifically need to be better centered to attain more accurate results.
  - PIND Test frequencies > 150Hz not beneficial
  - Large particles > 1mil in size more likely to be detected
  - Small packages with small particles – detection issue
  - Location of device under test affects particle detection results

Longer Shock Pulse Width Task Proposal

- Previous testing indicated need for improvements in particle detection.
- Spectral Dynamics proposed increasing shock pulse width during the May 2017 JEDEC meeting.
- Test method shock pulse width – 100µS maximum. Current shock pulse not close to maximum pulse width.
- Theory of longer shock pulse width – particle moves for a longer period of time potentially enhancing particle detection.

Longer Shock Pulse Width Task Proposal

Questions and more questions…

- How long is pulse width for one shock?
- Are equipment modifications needed?
- Is there a plan to verify this proposal?

Longer Shock Pulse Width Task Proposal Questions

- How long is pulse width for one shock currently? It depends on size of transducer/ shaker and varies between PIND equipment manufacturers.
  - Manufacturer X- 1 inch transducer/ shaker pulse width is ~ 40µS, 6-inch transducer/ shaker pulse width is ~ 100µS.
  - Manufacturer Y – pulse width is ~ 40µS, 6-inch transducer/ shaker pulse width is ~ 100µS.

Longer Shock Pulse Width Task Proposal Questions

- Are PIND equipment modifications needed for longer pulse width?
  - Yes, equipment modifications would be required on PIND test equipment at manufacturer facility.
- Is there a plan to verify this proposal?
  - A test plan has been developed and reviewed.

Longer Shock Pulse Width Task Proposal Test Plan

- Additional review of the test plan was recently completed with the following additions:
  - Sample parts are to be tested as received.
  - No pre-bake
  - No pre-conditioning
  - No degaussing allowed
  - Deviate from the test method in that only 1 test pass will be run each day instead of maximum of 5 runs

Longer Shock Pulse Width Task Proposal Test Plan

- Component supplier buy in – samples for testing
  - Discrete and microcircuit component suppliers are providing samples
  - Various package types for testing
  - Samples consist of non-seeded, seeded, and reject devices

Longer Shock Pulse Width Task Proposal Test Plan

- Facilities supporting PIND testing initially
  - NASA MSFC
  - NSWC Crane
  - Spectral Dynamics – standard and longer shock pulse width, and
  - B&W Engineering standard pulse width

Longer Shock Pulse Width Task Proposal Test Plan

- PIND testing will be performed as per the test method requirements for standard pulse width.
  - STU test
  - System noise verification
  - Shock pulse characterized at each test facility
  - Package cavity height determined

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

- PIND testing will be performed as per the test method requirements for standard pulse width.
  - Device serialization performed at Manufacturer or MSFC
  - Test frequency calculated per test method
  - Standard device handling precautions will be required
  - Test samples are combination of seeded, non-seeded, and PIND rejects
  - Characterize PIND test equipment to verify detection capability per package style

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

- PIND testing will be performed as per the test method requirements for standard pulse width.
  - Sample devices PIND testing on first day and record test results
  - Test again on second day and record test results
  - Package parts and ship to next test facility. Data recorded to be sent to MSFC
  - Spectral Dynamics will test parts using standard PIND tester and record results

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

- PIND testing will be performed as per the test method requirements for standard pulse width.
  - Spectral Dynamics will test parts one time each day for 2 consecutive days using longer shock pulse and record results. Data sent to MSFC for compilation.
  - Spectral Dynamics to ship parts to B&W Engineering

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

- PIND testing will be performed as per the test method requirements for standard pulse width.
  - B&W Engineering to test parts using standard PIND tester and record results. Ship data and sample parts to MSFC.
  - MSFC will compile and evaluate test data. Publish test report results.

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

Test Facility Standard PIND test results												
Equipment manufacturer & model	Device part number	Package type	Serial Number	Cavity height In mils	PIND Freq (Hz)	Pulse Width in mS	Shock Pulse in g's	Vibration detection				P/F?
								Vib 1	Vib 2	Vib 3	Vib 4	

Table 2. Test facility PIND equipment setup log

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

Test Facility Standard PIND test results												
Equipment manufacturer & model	Device part number	Package type	Serial Number	Cavity height In mils	PIND Freq (Hz)	Pulse Width 40 µS	Shock Pulse in g's	Vibration detection				P/F?
								Vib 1	Vib 2	Vib 3	Vib 4	

Table 3. Test facility PIND detection results for standard shock pulse width (~40 µs)

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

Test Facility Longer Shock Pulse Width PIND test results												
Equipment manufacturer & model	Device part number	Package type	Serial Number	Cavity height In mils	PIND Freq (Hz)	Pulse Width in mS	Shock Pulse in g's	Vibration detection				P/ F?
								Vib1	Vib 2	Vib 3	Vib 4	

Table 4. Test facility PIND detection results for longer shock pulse width (~100μs)

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

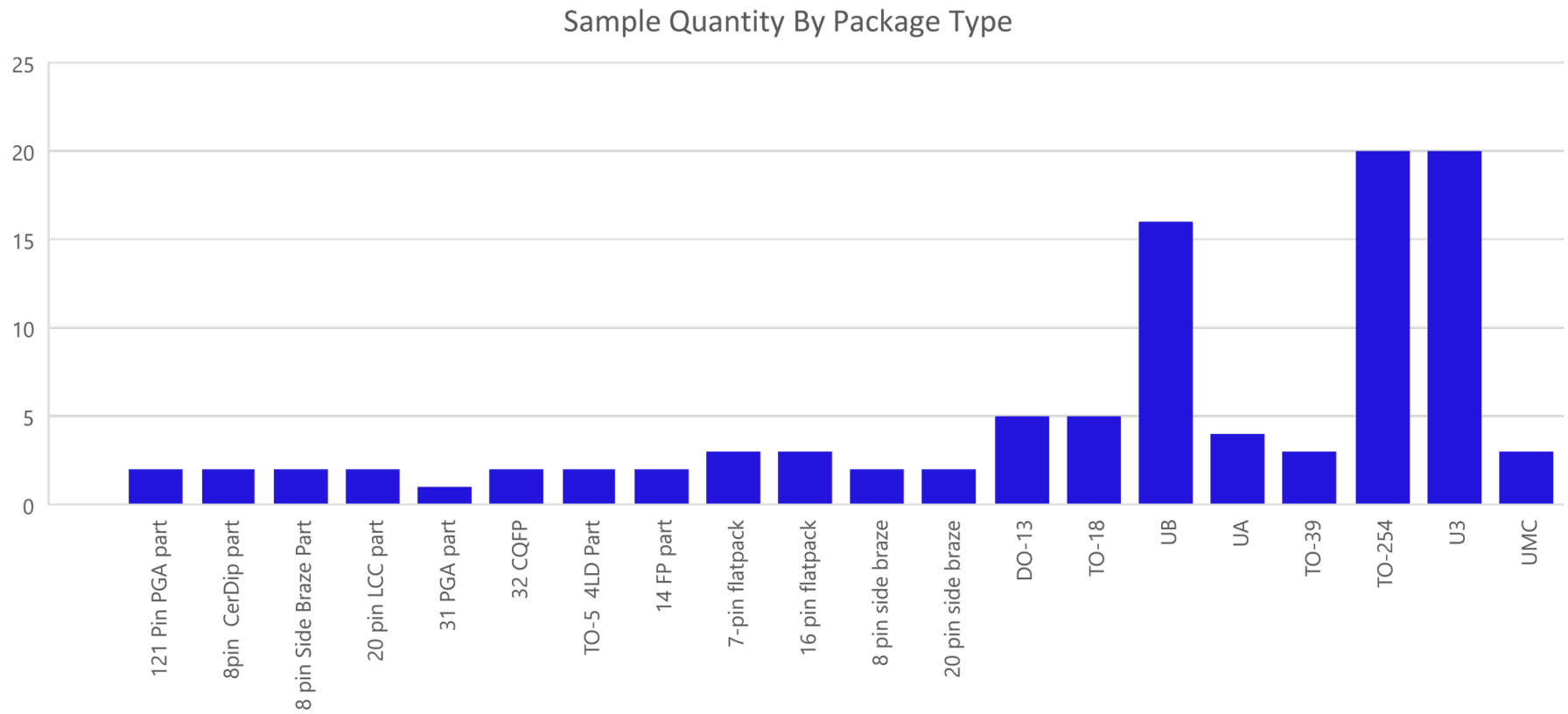


Chart 1. Sample quantity by package type

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

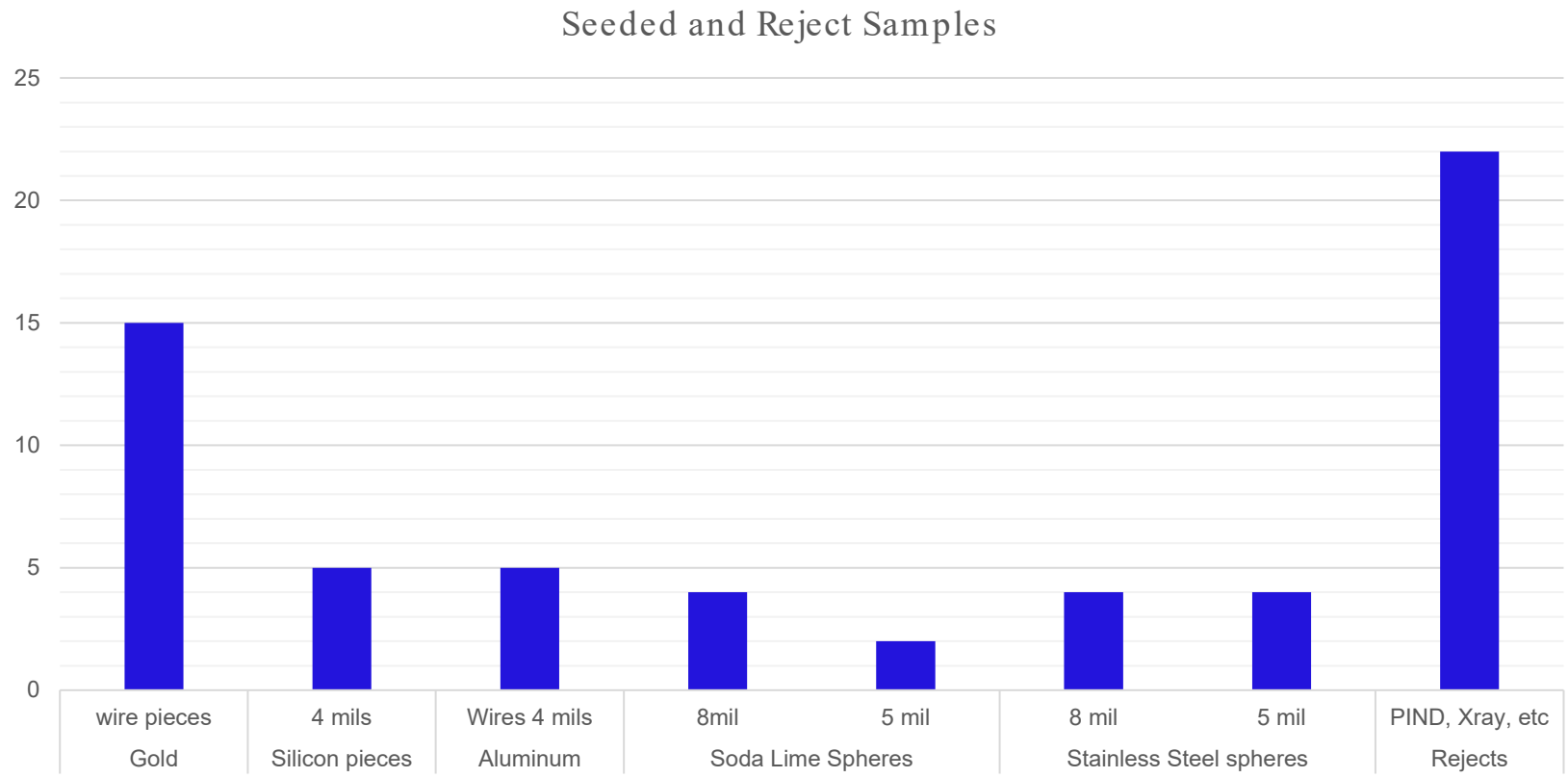


Chart 2. Particle composition

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

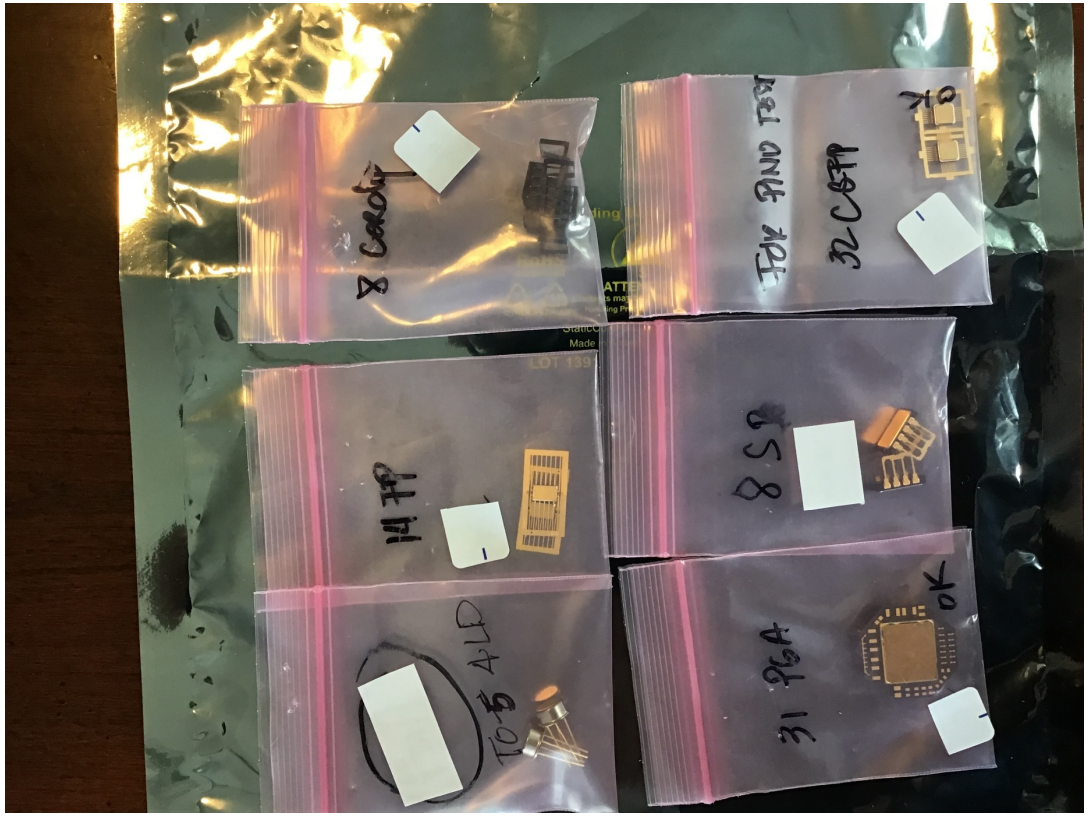


Figure 1. PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

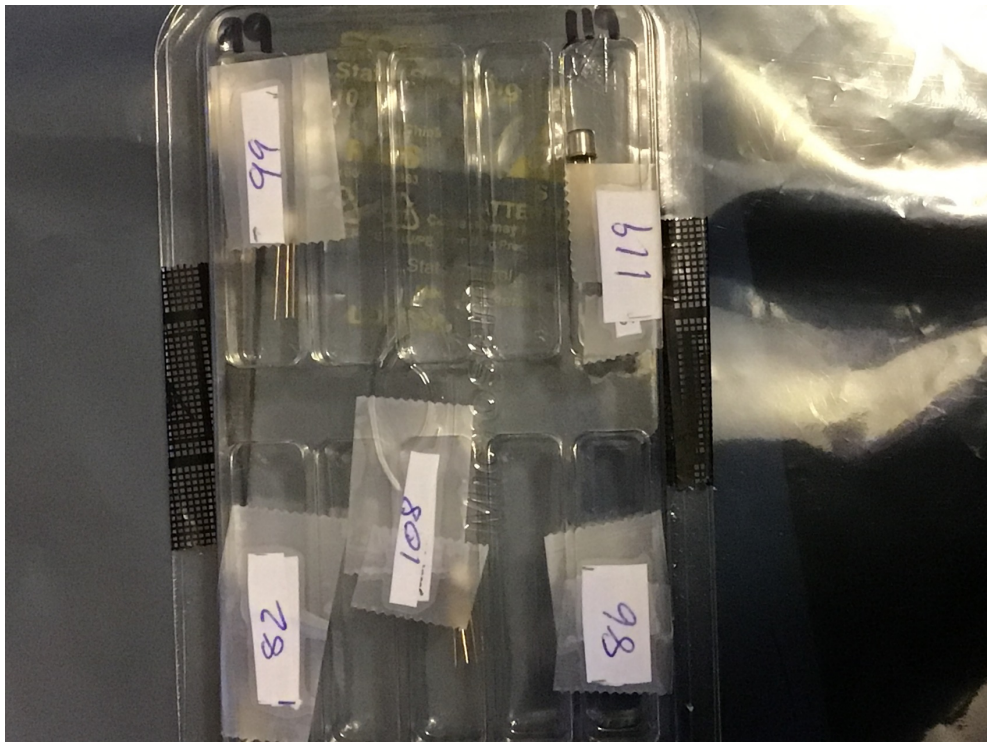
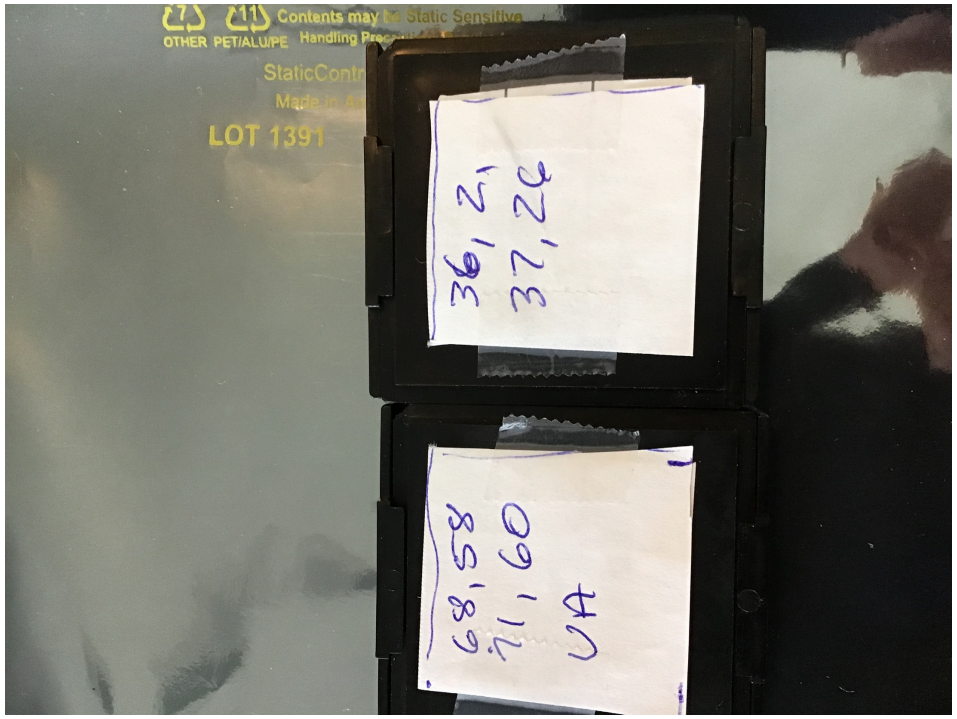


Figure 2. initial TO-39 and TO-18 PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d



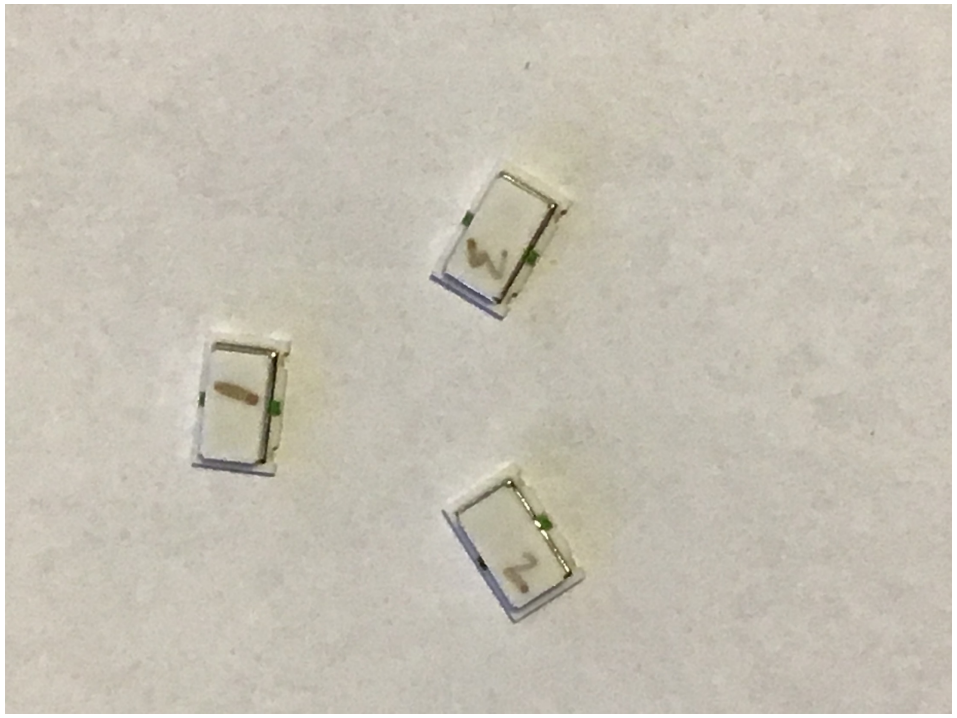
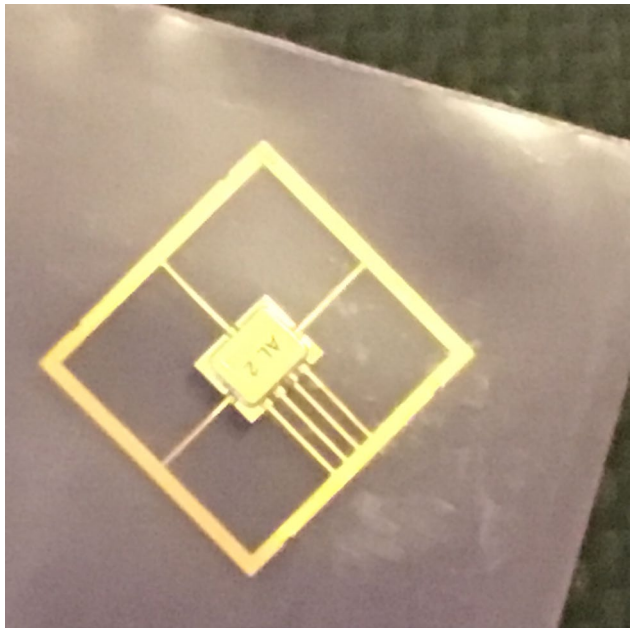


Figure 3. UA & UB, and UMC PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d



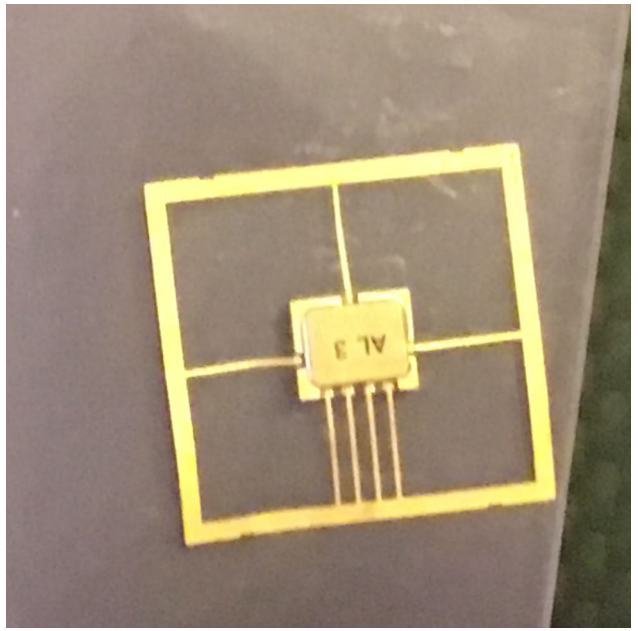
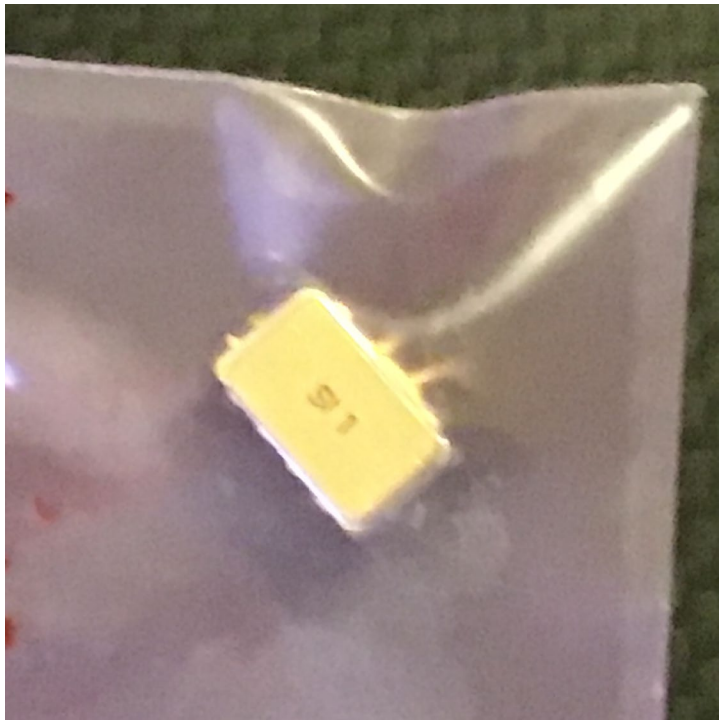


Figure 4. 7 pin flat pack PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d



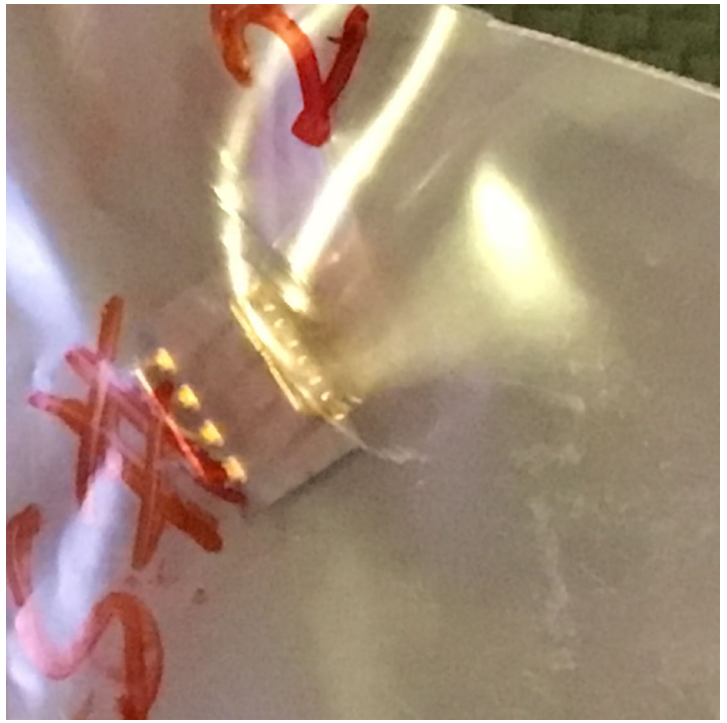
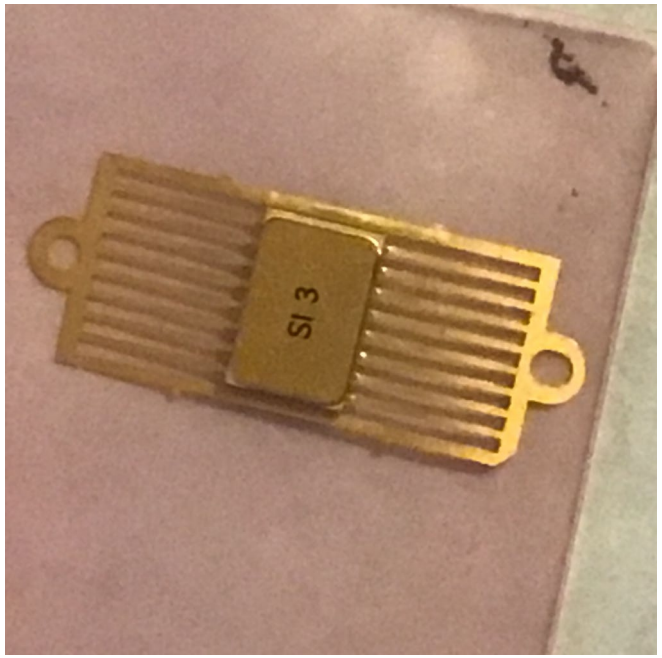
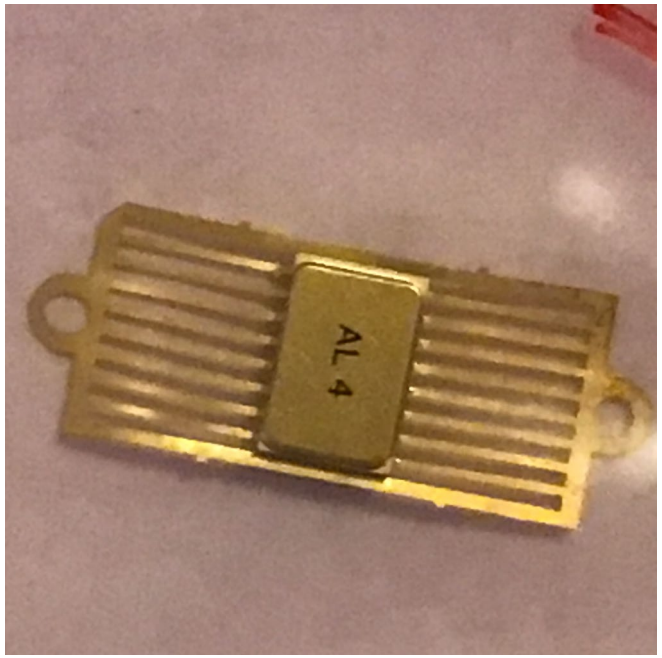


Figure 5. 8 pin Side brazed package PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d





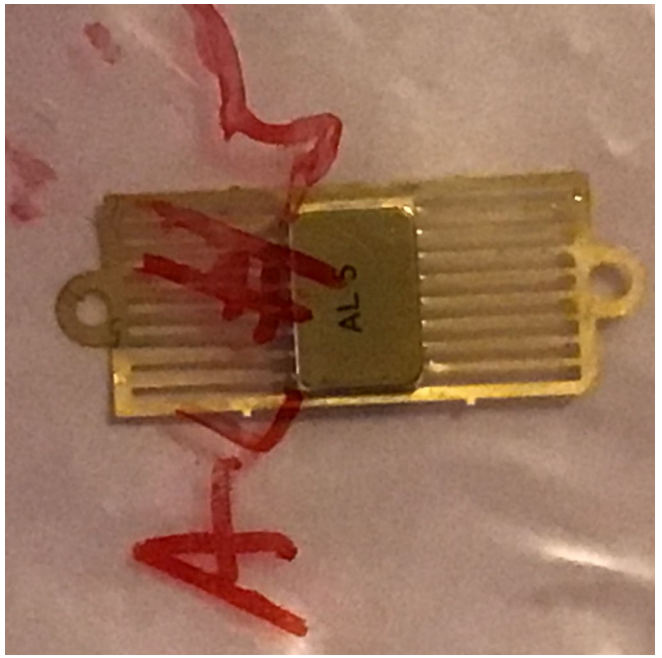
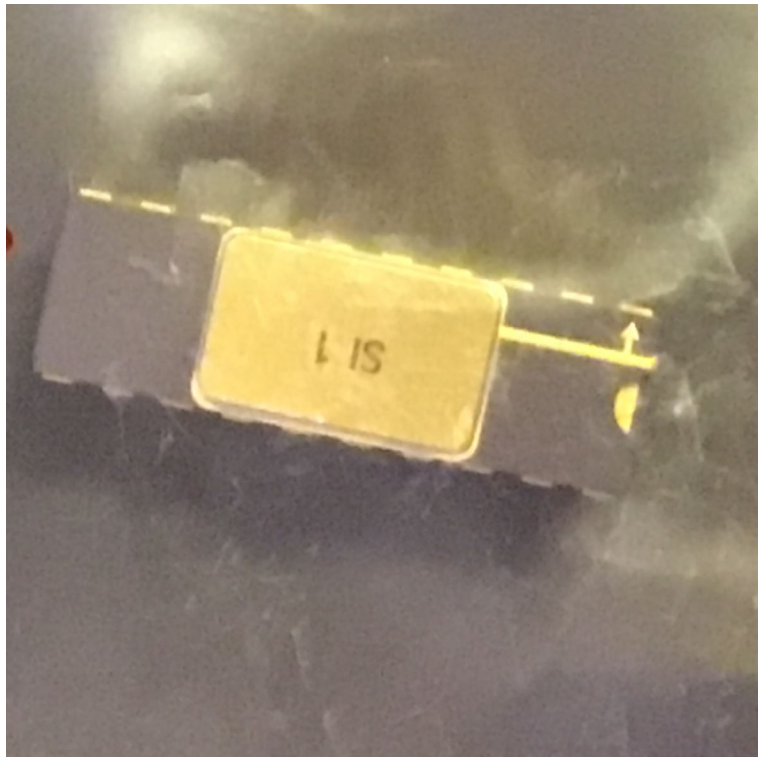


Figure 6. 16 pin flat pack PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d



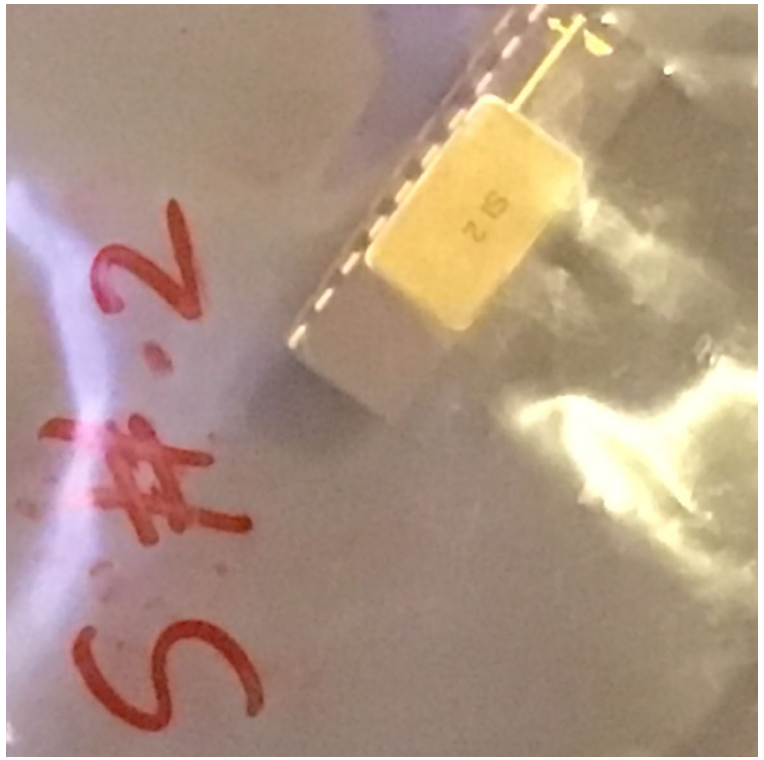


Figure 7. 20 Pin Side Braze PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

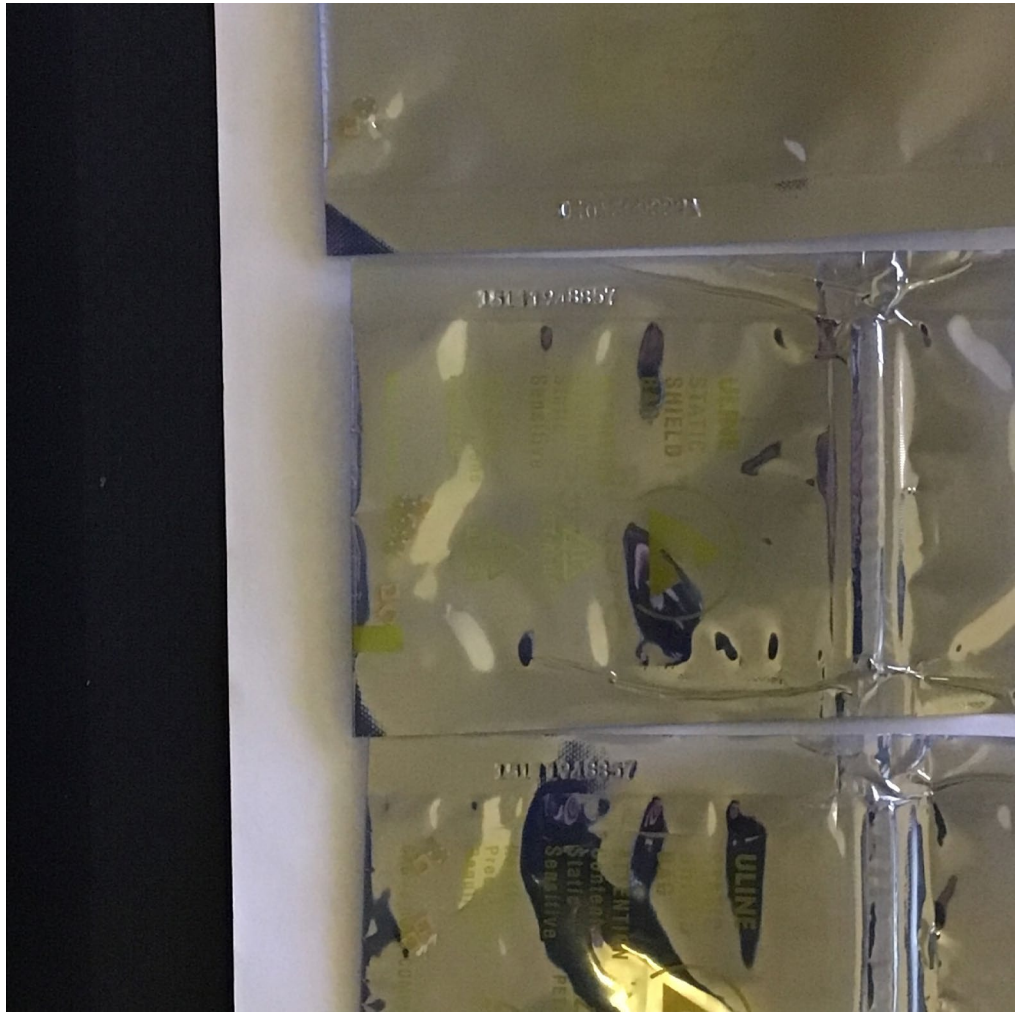


Figure 8. UB PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

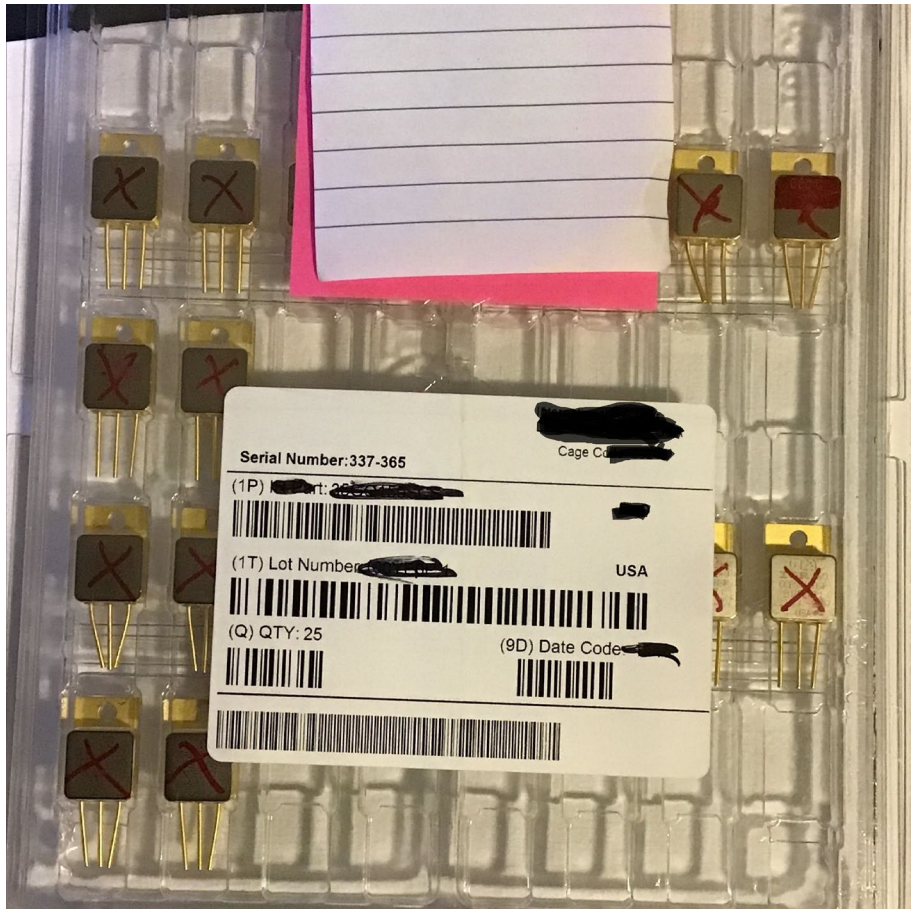


Figure 9. TO-254 and U3 PIND test samples

Longer Shock Pulse Width Task Proposal Test Plan Cont.'d

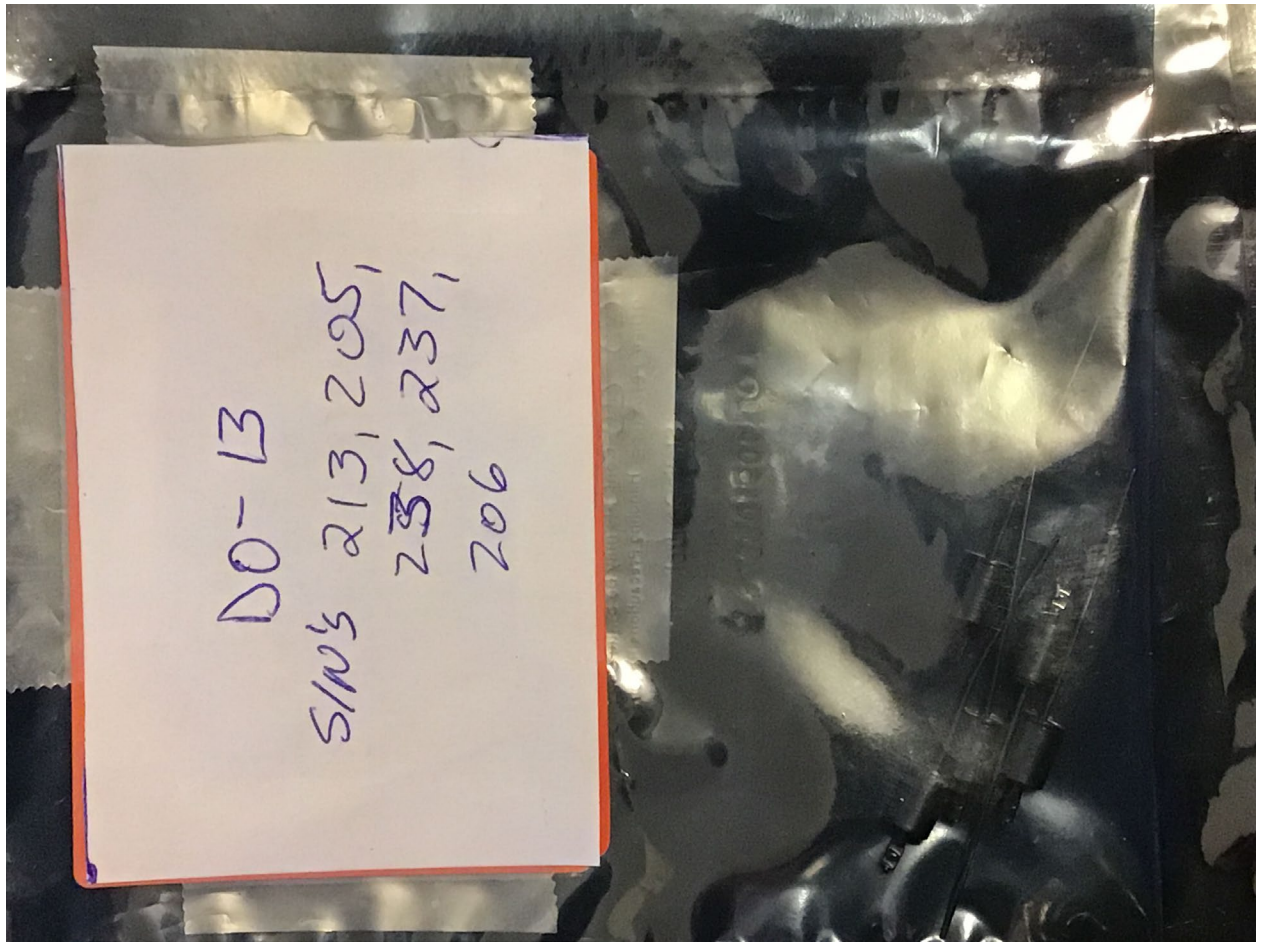
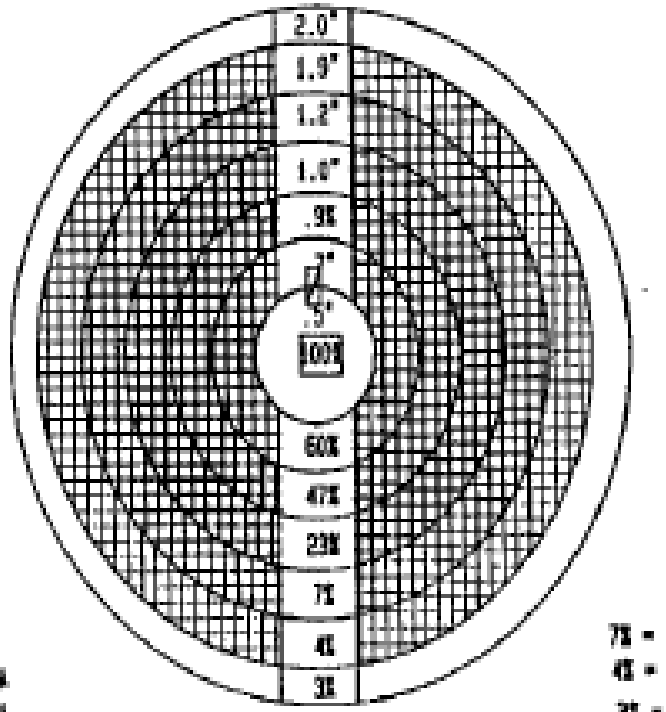


Figure 10. DO-13 PIND test samples

Longer Shock Pulse Width Task Proposal

- Copy of transmissibility response of a PIND Transducer Test Platform performed by Steward J. Slykhous of Spectral Dynamics. As can seen by his evaluation the center of the transducer produces more repeatable results.



TRANSMISSIBILITY RESPONSE

100% = 0 - 0.5 IN DIA AREA
60% = 0.5 - 0.7 IN DIA AREA
47% = 0.7 - 0.9 IN DIA AREA
23% = 0.9 - 1.0 IN DIA AREA

7% = 1.0 - 1.2 IN DIA AREA
4% = 1.2 - 1.9 IN DIA AREA
3% = 1.9 - 2.0 IN DIA AREA